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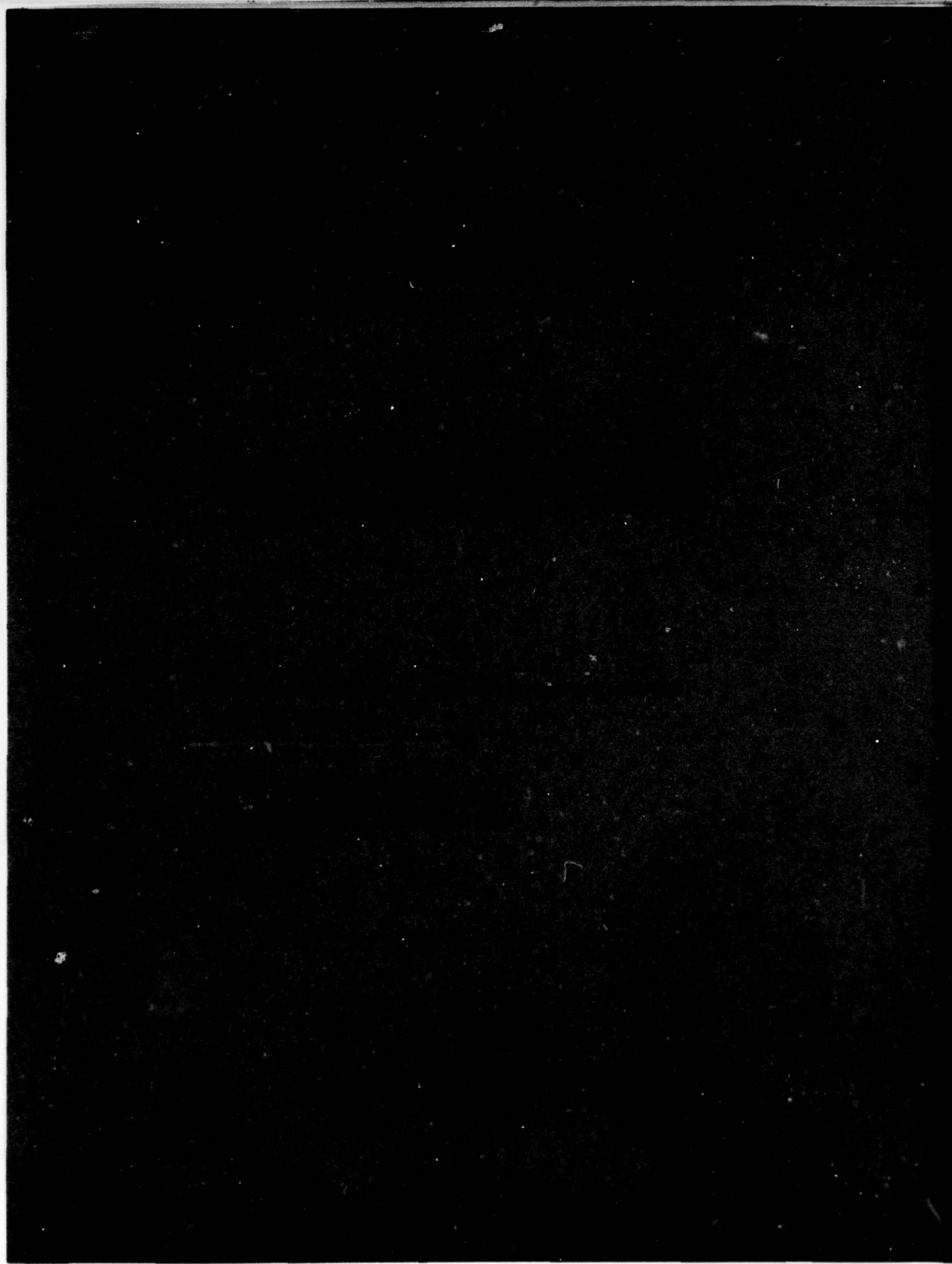
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ADVANCED ELECTRONIC TECHNOLOGY.

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QUARTERLY TECHNICAL SUMMARY REPORT

TO THE

AIR FORCE SYSTEMS COMMAND

10

Alan J. McLaughlin
Alan L. McWhorter

1 MAY - 31 JULY 1978

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INTRODUCTION

This Quarterly Technical Summary covers the period 1 May through 31 July 1978. It consolidates the reports of Division 2 (Data Systems) and Division 8 (Solid State) on the Advanced Electronic Technology Program.

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DATA SYSTEMS
DIVISION 2

INTRODUCTION

This section of the report reviews progress during the period 1 May through 31 July 1978 on Data Systems. Separate reports describing other work of Division 2 are issued for the following programs:

Seismic Discrimination	ARPA/NMRO
Distributed Sensor Networks	ARPA/IPTO
Education Technology	Bureau of Mines, ARPA/CTO, AFCS
Network Speech Processing	OSD-DCA
Voice Conferencing Technology	OSD-DCA
Digital Voice Processing	AF/ESD
JTIDS Speech Processing	AF/ESD
Packet Speech	ARPA/IPTO
Wideband Integrated Voice/Data Technology	ARPA/IPTO
Radar Signal Processing Technology	ARMY/BMDATC
Nuclear Safety Designs	NRC

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DIGITAL INTEGRATED CIRCUITS
GROUP 23

I. INTRODUCTION

The emphasis this quarter was on processing of the new serial/parallel converter and process improvements on the MNOS memory chip. Test results on both should be obtained in the next quarter.

II. HIGH-SPEED DIGITAL CIRCUITS

A. Serial/Parallel Converter

The first wafers of the new version of the serial/parallel converter are near completion. Simulation results indicate that 1-GHz serial operation should be attainable over a range of achievable transistor f_T values.

B. MUDPAC (16- × 16-Bit Multiplier Chip)

Logic design for an improved multiplier with an extended accumulator utilizing pipeline organization has been developed. With the pipeline design, a new multiplication can be started as soon as the last partial product of the previous multiplication is finished. Carry propagation from the previous multiplication into high-order accumulator bits is overlapped with generation and accumulation of the succeeding product in lower-order bits. This permits a new multiplication to be started every 16 clock periods, with an additional delay of 30 clock periods after the final multiply before the 40-bit accumulation of products is available. Detailed design of the logic, circuits, and pin-out are in progress. Because of the major changes in logic, work on the previous multiplier test chip has been terminated. A new test chip for the pipeline multiplier is being designed to determine trade-offs on power, propagation delay, and device geometry for poly-ox process ECL logic circuits for the pipeline multiplier.

III. MNOS MEMORY

A. 64K-Chip Fabrication

The first wafers from the second group of MNOS 64K-chip wafer starts are nearing completion. The most significant process improvement for these wafers is a change to low-pressure chemical vapor deposition of the memory nitride. This process has resulted in improved thickness control and write characteristics. A different deposition technique for first-level metal has reduced mobile ion contamination of the gate dielectric by more than an order of magnitude. Ion implantation of decoding transistor source and drain regions has reduced shorting, and in future runs further improvement is expected with the use of an MNOS gate dielectric. A new photomasking sequence has reduced field nitride loss during stripping of the Rotox implant mask.

A 3 × 3 memory array which is fabricated on the 64K chip has been successfully operated. Individual decoding transistors have also been exercised.

B. "Amorphous" Isolation

X-ray-diffraction and optical-transmission experiments were performed on neon-implanted silicon samples to determine the structural properties of the resulting material. The data lead

to the conclusion that the silicon after the implant is not amorphous, but is rather a crystal with a high defect density. It appears that a neon dose of $10^{15}/\text{cm}^2$ is insufficient to amorphize the silicon. This is reasonable if the temperature of the wafer increases during an implant, which has been confirmed experimentally. A model of the damaged material used for isolation is proposed. The damage produces a large density of states in the center of the silicon band gap where the Fermi energy is pinned so that the number of free carriers is small. This also implies that the conductivity should increase exponentially with reciprocal temperature, which has been observed. Barriers at the boundary between silicon and the damaged material arise because of the difference in Fermi energy in the two materials. They are slightly more complicated than the amorphous-crystalline silicon junctions described by Brodsky,* but should have the same basic characteristics.

IV. PROCESS DEVELOPMENT AND TESTING

A. Laser Annealing

Preliminary experiments confirmed that laser annealing of amorphous arsenic implants produces good diodes. Further experiments are being planned, and an argon laser has been ordered.

B. Plasma Etching

A plasma-etching process using a SiF_4 and O_2 mixture has been developed which etches silicon nitride with no measurable attack on silicon, thermox, or CVD oxide.

C. Testing

A pulsed capacitance test has been added to the TIC testing system to permit the evaluation of dopant profiles in the deep depletion region.

An interface to a digital oscilloscope has been built, a second wafer prober interfaced to the testing system, and the TIC subroutine library expanded with new plotting and trigonometric function routines.

* M. H. Brodsky and G. H. Dohler, "A New Type of Junction: Amorphous/Crystalline," CRC Critical Reviews, Solid State Sciences, November 1975.

COMPUTER SYSTEMS
GROUP 28

The batch-processing system, OS/VS1, has been updated to IBM's Release 6 level. One of the principal new features it contains is an extension of support from 4 Mbytes of real main storage to 16 Mbytes. Since the installed IBM 370/168 computer has only 3 Mbytes of real main storage, this extension has no significance at all in native mode operations. However, when VS is run on a virtual machine under the VM/370 time-sharing system, its virtual main storage is made as large as possible to eliminate the double overhead of paging under both systems. With the extension of support to 16 Mbytes, this means that the VSBATCH operation under VM, particularly during off hours, can be more productive.

In parallel with continuing work on the operating system, there is a broad effort in progress to make the computer more useful and accessible to a wide range of Laboratory applications. This effort currently has two aspects.

The first, which is broadly categorized as education, aims at providing users and potential users with the information and training needed to use available facilities. At the lower end of this spectrum there is a beginning-level class made up of units of "how-to-do-it" training in basic system components. A pilot version of this class was developed and presented to an initial group during this quarter. Plans call for refining the material and producing an automated version that might be on-line to the computer, on video tape, or on a Lincoln-developed audio-visual training device. Another series is being developed to explore and present modern programming concepts and techniques. This material will probably be in a seminar format and will explore such subjects as structured programming, chief programmer teams, aids to program design, and similar matters in the area of software engineering.

The second aspect of improving the usefulness of the computer is that of providing a variety of user packages. The intent here is to emphasize software that is simple and efficient from the user's point of view. The state of the art in software has certainly progressed to a point where many of the esoteric language and procedure barriers can be cleared from the path of end users. Two examples of such software provided during this quarter are the WATFIV compiler and an interactive plotting system. The former is basically a Fortran compiler which includes many features designed specifically to aid a programmer during the checkout stage. The plotting package, being developed at Lincoln, is also user oriented and is intended to make graphic presentation of data far less of a clerical and procedural burden than it now is.

SOLID STATE
DIVISION 8

INTRODUCTION

This section of the report summarizes progress during the period 1 May through 31 July 1978. The Solid State Research Report for the same period describes the work of Division 8 in more detail. Funding is primarily provided by the Air Force, with additional support provided by the Army, ARPA, NSF, and DOE.

A. L. McWhorter
Head, Division 8
I. Melngailis
Associate Head

DIVISION 8 REPORTS
ON ADVANCED ELECTRONIC TECHNOLOGY

15 May through 15 August 1978

PUBLISHED REPORTS

Journal Articles

<u>JA No.</u>			
4753	Surface Relief Gratings of 3200-Å-Period Fabrication Techniques and Influence on Thin-Film Growth	D. C. Flanders H. I. Smith	J. Vac. Sci. Technol. <u>15</u> , 1001 (1978)
4755	Doppler-Limited Spectra of the C-H Stretching Fundamentals of Formaldehyde	A. S. Pine	J. Mol. Spectrosc. <u>70</u> , 167 (1978)
4776	Explanation of the 6-Fold LEED Patterns from Polar (0001) and (000 $\bar{1}$) ZnO Surfaces	V. E. Henrich H. J. Zeiger E. I. Solomon* R. R. Gay*	Surf. Sci. <u>74</u> , 682 (1978)
4790	Wavelength Dependence of GaAs Directional Couplers and Electrooptic Switches	F. J. Leonberger J. P. Donnelly C. O. Bozler	Appl. Opt. <u>17</u> , 2250 (1978)
4793	1-mJ Line-Tunable Optically Pumped 16 μ m Laser	R. M. Osgood, Jr.	Appl. Phys. Lett. <u>32</u> , 564 (1978)
4799	Ultraviolet Photoemission Measurements of the Band Structure of TiO _x (0.93 \leq x \leq 1.15)	V. E. Henrich H. J. Zeiger T. B. Reed*	Phys. Rev. B <u>17</u> , 4121 (1978)
4803	Vibrational Energy Relaxation and Exchange in Liquid N ₂ -CO-OCS Mixtures	S. R. J. Brueck R. M. Osgood, Jr.	J. Chem. Phys. <u>68</u> , 4941 (1978)
4811	Surface Defects and the Electronic Structure of SrTiO ₃ Surfaces	V. E. Henrich G. Dresselhaus H. J. Zeiger	Phys. Rev. B <u>17</u> , 4908 (1978)
4815	Far-IR Heterodyne Radiometric Measurements With Quasioptical Schottky Diode Mixers	H. R. Fetterman P. E. Tannenwald B. J. Clifton C. D. Parker W. D. Fitzgerald N. R. Erickson*	Appl. Phys. Lett. <u>33</u> , 151 (1978)

* Author not at Lincoln Laboratory.

Meeting Speeches

MS No.

- | | | | |
|------|---|---|--|
| 4436 | Photoemission Studies of Molecular Adsorption on Oxide Surfaces | V. E. Henrich | In <u>Inelastic Electron Tunneling Spectroscopy</u> , T. F. Wolfram, Ed. (Springer-Verlag, New York, 1978), p. 160 |
| 4437 | Alignment of X-Ray Lithography Masks Using a New Interferometric Technique - Experimental Results | S. Austin
H. I. Smith
D. C. Flanders | J. Vac. Sci. Technol. <u>15</u> , 984 (1978) |
| 4438 | Polyimide Membrane X-Ray Lithography Masks - Fabrication and Distortion Measurements | D. C. Flanders
H. I. Smith | J. Vac. Sci. Technol. <u>15</u> , 995 (1978) |
| 4543 | Chemisorbed Phases of O ₂ on TiO ₂ and SrTiO ₃ | V. E. Henrich
G. Dresselhaus
H. J. Zeiger | J. Vac. Sci. Technol. <u>15</u> , 534 (1978) |
| 4544 | Surface Photovoltage Experiments on SrTiO ₃ Electrodes | J. G. Mavroides
D. F. Kolesar | J. Vac. Sci. Technol. <u>15</u> , 538 (1978) |
| 4651 | Acoustoelectric Surface Wave Devices for Programmable Signal Processing | J. H. Cafarella | 1978 IEEE International Symposium on Circuits and Systems Proceedings (IEEE, New York, 1978), pp. 392-399 |
| 4689 | New Applications of Submicrometer Structures in Materials Science and Biology | H. I. Smith
D. C. Flanders
D. C. Shaver | Proc. Scanning Electron Microscopy '78, Los Angeles, 17-21 April 1978, Vol. I, pp. 33-40 |

* * * * *

UNPUBLISHED REPORTS

Journal Articles

JA No.

- | | | | |
|-------|--|--|---------------------------------|
| 4791A | Surface States on n-Type SrTiO ₃ | S. Ellialtioglu*
T. Wolfram*
V. E. Henrich | Accepted by Solid State Commun. |
| 4809 | High Na ⁺ -Ion Conductivity in Na ₅ YSi ₄ O ₁₂ | H. Y-P. Hong
J. A. Kafalas
M. Bayard | Accepted by Mater. Res. Bull. |
| 4814 | Optical and Electrical Properties of CdGeAs ₂ | G. W. Iseler
H. Kildal
N. Menyuk | Accepted by J. Electron. Mater. |

* Author not at Lincoln Laboratory.

JA No.

4823	Vapor Phase Growth of $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ Epitaxial Layers	P. Vohl C. M. Wolfe*	Accepted by J. Electron. Mater.
4826	Thermal Conductivity and Specific Heat of $\text{NdP}_5\text{O}_{14}$	S. R. Chinn W. K. Zwicker*	Accepted by J. Appl. Phys.
4835	Condon Internal Diffraction in the $\text{O}_u^+ \rightarrow \text{O}_g^+$ Fluorescence of Photo-associated Hg_2	D. J. Ehrlich R. M. Osgood, Jr.	Accepted by Phys. Rev. Lett.
4841	Λ -Doubling in the $v = 0 \rightarrow 2$ Overtone Band in the Infrared Spectrum of NO	A. S. Pine J. W. C. Johns* A. G. Robiette*	Accepted by J. Mol. Spectrosc.
4847	Molecular-Beam Tunable-Diode-Laser Subdoppler Spectroscopy of a Λ -Doubling in Nitric Oxide	A. S. Pine K. W. Nill*	Accepted by J. Mol. Spectrosc.
4856	Gap-Coupled InSb/LiNbO ₃ Acoustoelectric Convolver Operating at 77 K	F. J. Leonberger R. W. Ralston S. A. Reible	Accepted by Appl. Phys. Lett.

Meeting Speeches[†]

MS No.

4540A	Efficient Infrared Third Harmonic Generation in Cryogenic Liquids	H. Kildal S. R. J. Brueck	IX Natl. Conf. on Lasers and Nonlinear Optics, Leningrad, USSR, 13-16 June 1978
4577	High Na^+ -Ion Conductivity in $\text{Na}_5\text{YSi}_4\text{O}_{12}$	H. Y-P. Hong J. A. Kafalas M. Bayard	28th Power Sources Symp., Atlantic City, New Jersey, 12-15 June 1978
4578	NASICON, A New Solid Electrolyte for Na-S Batteries	J. A. Kafalas H. Y-P. Hong	
4578A	NASICON, A New Solid Electrolyte for Na-S Batteries	J. A. Kafalas	Seminar, Environmental Impact Corp., Waltham, Massachusetts, 18 May 1978
4589	High-Efficiency GaAs Shallow-Homojunction Solar Cells	J. C. C. Fan C. O. Bozler	13th IEEE Photovoltaic Specialists Conf., Washington, DC, 5-8 June 1978
4616	Fabrication and Properties of New Solid Electrolytes	J. A. Kafalas H. Y-P. Hong	American Ceramics Society Mtg., Detroit, Michigan, 6-11 May 1978

* Author not at Lincoln Laboratory.

† Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

MS No.

4620	Submicrometer Spatial Period Surface Relief Gratings for Orienting Crystalline Overlayers	D. C. Flanders D. C. Shaver H. I. Smith	8th Intl. Conf. on Electron and Ion Beam Science and Technology, Seattle, Washington, 21-26 May 1978
4625	Lasing and Fluorescence in $K_5NdLi_2F_{10}$	A. Lempicki* B. McCollum* S. R. Chinn H. Y-P. Hong	10th Intl. Quantum Electronics Conf., Atlanta, Georgia, 29 May - 1 June 1978
4639	Studies of Electronically Excited Hg_2 for Use as a Laser Storage Medium	D. J. Ehrlich R. M. Osgood, Jr.	
4643	Infrared Double Resonance of Highly Vibrationally Excited SF_6	S. R. J. Brueck T. F. Deutsch	
4644	Laser Induced Breakdown of Cryogenic Liquids	S. R. J. Brueck H. Kildal	
4650	Efficient CW Optically Pumped $Ni:MgF_2$ Laser	P. F. Moulton A. Mooradian	
4742	High Resolution Double Resonance Spectroscopy of $v_3 = 2 \leftarrow 1$ Transitions in SF_6	P. F. Moulton A. Mooradian	
4743	Efficient Third Harmonic Generation in Liquid $CO-O_2$ Mixtures	S. R. J. Brueck H. Kildal	Intl. Luminescence Conf., Paris, 17 July 1978
4625A	Luminescence of New Stoichiometric Nd^{3+} Compounds	A. Lempicki* B. McCollum* S. R. Chinn H. Y-P. Hong	
4648	$GaInAsP/InP$ Lasers and Detectors for Fiber Optic Communications at 1.1 - 1.3 μm	J. J. Hsieh C. E. Hurwitz C. C. Shen	Electro '78 - Optical Guided Wave Transmission Technology, Boston, 23-25 May 1978
4656	Submillimeter Wavelength Surface Oriented Diode Mixers	R. A. Murphy G. D. Alley C. O. Bozler H. R. Fetterman P. E. Tannenwald B. J. Clifton	1978 IEEE-MTT-S Symp., Ottawa, Ontario, Canada, 27-29 June 1978
4658	High Sensitivity Submillimeter Heterodyne Receiver	H. R. Fetterman P. E. Tannenwald B. J. Clifton C. D. Parker W. D. Fitzgerald N. R. Erickson*	

* Author not at Lincoln Laboratory.

MS No.

4701	Solid State Electrochromic Displays Using Solid Electrolytes	M. Bayard	} Electronic Materials Conf., Santa Barbara, California, 28-30 June 1978
4702	Effect of H ₂ on Residual Impurities in GaAs MBE Layers	A. R. Calawa	
4708	Synthesis and Crystal Growth of CdGeP ₂	P. Vohl	
4703	Self-Broadening and ¹³ C/ ¹² C Isotope Intensity Ratios in the ν_3 -Band of Methane	A. S. Pine	} Molecular Spectroscopy Symp., Ohio State University, Columbus, 12-16 June 1978
4704	Torsional Splittings and Assignments in the Low Temperature Doppler-Limited Spectrum of the C-H Stretching Bands of Ethane	A. S. Pine W. J. Lafferty*	
4705	Λ -Doubling in the $v = 0 \rightarrow 2$ Overtone of NO	A. S. Pine J. W. C. Johns* A. G. Robiette*	
4730	The Growth of Large, Laser Quality Nd _x La _{1-x} P ₅ O ₁₄ Crystals	W. K. Zwicker* T. Kovats* S. R. Chinn	4th American Conf. on Crystal Growth, National Bureau of Standards, Gaithersburg, Maryland, 16-20 July 1978
4731	UPS Studies of the Chemisorption of CO, NH ₃ and H ₂ O on ZnO	R. R. Gay E. I. Solomon* V. E. Henrich H. J. Zeiger	38th Physical Electronics Conf., Oak Ridge National Laboratory, Oak Ridge, Tennessee, 19-21 June 1978

* Author not at Lincoln Laboratory.

SOLID STATE DIVISION 8

I. SOLID STATE DEVICE RESEARCH

Several 12-element HgCdTe 10.6- μm photodiode arrays have been fabricated and tested with average heterodyne sensitivities better than 4.8×10^{-20} W/Hz and 7.5×10^{-20} W/Hz at 760 MHz and 1.5 GHz, respectively. Typical quantum efficiencies have now been increased to the range of 70 to 85 percent. Optimum performance in the heterodyne mode of operation was obtained using 0.3 to 0.6 mW of CO_2 local-oscillator power, which produced a 2- to 4-mA photocurrent.

The residual impurity concentration in molecular-beam epitaxially grown GaAs films was found to be reduced by a factor of about 50 to approximately $4 \times 10^{15} \text{ cm}^{-3}$ when hydrogen is introduced during deposition. The band-edge photoluminescence was enhanced, whereas the deep-level photoluminescence decreased as the purity of the films increased.

II. QUANTUM ELECTRONICS

Continuous tuning of the CW Ni:MgF_2 laser has been achieved over a 460-cm^{-1} range from 1.61 to 1.74 μm . The system employed a 1.33- μm Nd:YAG pump laser and an intracavity birefringent filter.

Lasing has been observed in $\text{K}_5\text{NdLi}_2\text{F}_{10}$, a new high-Nd-concentration material. The product of lifetime and cross section is larger than that in $\text{NdP}_5\text{O}_{14}$, and the temperature and Nd concentration dependence of the lifetime are also different.

Efficient third-harmonic generation can be obtained by placing two nonlinear crystals in tandem, with the first oriented for second-harmonic generation and the second for sum mixing. By using such a two-step technique, frequency tripling of CO_2 mini-TEA laser radiation has been carried out in CdGeAs_2 with an average external conversion efficiency of 1.5 percent.

A double-pass tight-focusing geometry having a confocal parameter of only 1.0 cm was used with 8-nsec CO_2 laser input pulses to obtain 4-percent energy-conversion efficiency for third-harmonic generation in a liquid $\text{CO}_2\text{-O}_2$ mixture.

Experiments to investigate the feasibility of optical energy extraction from molecular mercury with an infrared laser have been performed. An infrared-induced enhancement has been observed at 300 nm, which is 10 times the thermal value.

An efficient thallium laser at 535 and 337.6 nm has been developed based on the photolysis of thallium iodide with the 193-nm output of an ArF laser. An energy efficiency of 14 percent has been measured for conversion of the pump into the thallium laser emission.

Harmonic heterodyne detection in conjunction with a surface-acoustic-wave (SAW) dispersive delay line has been used to perform real-time spectral analysis of submillimeter laser signals. Detailed information on the longitudinal modes and spectral bandwidth of the pulsed D_2O laser (385 μm) has been obtained for the first time using this technique.

III. MATERIALS RESEARCH

A technique has been developed for using ion-beam sputtering to deposit highly transparent, highly conducting Sn-doped In_2O_3 (ITO) films for possible applications in GaAs solar cells. In

initial experiments, such films have been utilized in two types of cells: those in which an ITO/p-GaAs heterojunction forms the charge-separation barrier, and shallow-homojunction cells in which the ITO forms a transparent ohmic contact to the upper n^+ -GaAs layer.

To assist in the development of experimental techniques for using laser heating to crystallize semiconductor films and to anneal ion-implantation damage in semiconductors, a theoretical model has been developed for calculating the temperature profiles of semiconductor samples heated with a scanned CW laser to temperatures below their melting points. Computer calculations utilizing this model have been carried out both for thin semiconductor films on metal-coated insulating substrates and for ion-implanted semiconductor samples.

IV. MICROELECTRONICS

The first prototype of the SAW/CCD buffer memory device has been tested at a CCD clock frequency of 100 kHz and at input signal frequencies between 80 and 130 MHz. The device operates without frequency folding between 85.6 and 128.3 MHz, within 300 kHz of the predicted values. The amplitude and phase of the output signal from the CCD track those of the input signal to the SAW device, as expected.

Two holographic masks have been fabricated which will act as lenses to convert a uniform laser-beam profile to a spherical wavefront. These masks are synthetic coding holograms, and consist of arrays of rectangular apertures built up from a minimum rectangle, which in this case was $3 \times 45 \mu\text{m}$.

V. SURFACE-WAVE TECHNOLOGY

A technique has been developed for precisely determining the phase and amplitude response of SAW devices over the relatively long delays and large bandwidths usually encountered in the devices. Measurements are made in a pulsed mode so that a number of sequential signals may be time resolved. A computer-controlled measurement system provides for the precise and rapid accumulation, analysis, and display of data from devices with time-bandwidth products of several thousand for frequencies up to 1250 MHz.

Perturbations in surface-wave propagation caused by coupling to nonpropagating bulk waves in shallow oblique- and normal-incidence groove gratings have been measured. Phase shifts upon transmission and shifts in fundamental stop-band frequency f_0 have been determined and compared with previous measurements of the magnitude of the reflection at the stop band near $2f_0$. The comparisons indicate a limitation of an existing model of grating interactions.

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